TECHNICAL NOTE

No. 1467

EFFECT OF VARIATION IN DIAMETER AND PITCH OF RIVETS

ON COMPRESSIVE STRENGTH OF PANELS

WITH Z-SECTION STIFFENERS

PANELS OF VARIOUS STIFFENER SPACINGS

THAT FAIL BY LOCAL BUCKLING

By Norris F. Dow and William A. Hickman

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

An experimental investigation is being conducted to determine the effect of varying the rivet diameter and pitch on the compressive strength of flat 24S-T aluminum-alloy Z-stiffened panels of the type for which design charts are available. The present part of the investigation is concerned with panels which have the smallest values of width-to-thickness ratio of the webs of the stiffeners given by the design charts and have such length that failure is by local buckling. The results showed that for these panels, regardless of their stiffener spacing, the compressive strengths increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets.

INTRODUCTION

The design and analysis of sheet-stiffener panels for aircraft structures have been the subject of extensive experimental and theoretical investigations, but the determination of the size and pitch of rivets for attaching sheet to stiffener is a problem that has not been adequately solved. In reference 1 charts and procedures are presented for the design of Z-stiffened panels to carry a given intensity of loading at a given panel length. The test data on which these design charts were based, however, were obtained for an arbitrary diameter and pitch of the rivets. An investigation is therefore being conducted in the Langley structures research laboratory of the NACA to determine the effect of a variation in the rivet

diameter and pitch on the strength of 24S-T aluminum-alloy panels with longitudinal Z-section stiffeners of the type for which the design charts of reference 1 were prepared.

Results are presented of the third series of tests for the investigation. Some results of the first series of tests, reported in reference 2, are combined herein with the results of the third series. Since any number of combinations of rivet diameter and pitch are possible for any panel; the results of the tests made in these first three series can cover only a small region on the design charts of reference 1. The first series of tests (reference 2) covered the region in which the panels have the closest stiffener spacings, the smallest value of width-to-thickness ratio for the webs of the stiffeners, and such lengths that failure is by local buckling. The second series of tests (reference 3) covered the same region as the tests of reference 2 except for the limitation on the panel lengths. The third series of tests, with which the present paper is concerned, covers the region in which the panels have the smallest value of width-to-thickness ratio for the webs of the stiffeners, such lengths that failure is by local buckling, and no limitation on the stiffener spacing. Further testing will be required to determine the effect of rivet diameter and pitch on panels having higher values of width-to-thickness ratio for the webs of the stiffeners.

SYMBOLS

L length of specimen, inches

ρ radius of gyration, inches

L/p slenderness ratio

W width of specimen, inches

bg spacing of stiffeners on sheet, inches

bA width of attachment flange of stiffeners, inches

by width of web of stiffeners, inches

by width of outstanding flange of stiffeners, inches

ts thickness of sheet, inches

tw thickness of web of stiffeners, inches

- d diameter of rivets, inches
- p pitch of rivets, inches
- h depth of countersink for rivets, inches
- ocy compressive yield stress for material, ksi
- σ_f average compressive stress at failing load for any specimen, ksi
- c coefficient of end fixity in Euler column formula
- Pi compressive load per inch of panel width, kips per inch
- R radius of bend

TEST SPECIMENS AND METHOD OF TESTING

The specimens consisted of 24s-T aluminum-alloy panels having longitudinal Z-section stiffeners as shown in figures 1 and 2. Seven stiffener spacings $\left(\frac{bS}{tS}=25,\ 30,\ 35,\ 40,\ 50,\ 60,\ and\ 75\right)$ were investigated. The stiffeners on all panels were identical. Two thicknesses of sheet were used to give two ratios of stiffener thickness to sheet thickness: $\frac{tW}{tS}=1.00$ and 0.63. The lengths of the panels were so chosen $\left(\frac{L}{\rho}=20\right)$ that no column failures occurred. The proportions $\frac{bW}{t_W}=20$, $\frac{bA}{t_W}=9.5$, and $\frac{bF}{bW}=0.4$ were chosen to give the panels from the design charts of reference 1 that have the smallest values of width-to-thickness ratio for the webs of the stiffeners. In order to allow for the larger rivets used in the present investigation, the value of $\frac{bA}{t_W}$ for the panels was slightly larger than that used for the panels of reference 1 which had $\frac{tW}{t_C}=1.00$.

The rivets used throughout the investigation were Al7S-T flathead rivets (AN442AD). Both the diameter and pitch of the rivets were varied for each ratio of sheet thickness to stiffener thickness, as is shown in table 1. The minimum rivet pitch used in all cases was equal to three times the rivet diameter. On all panels the rivets were driven by the NACA flush-riveting process in which the

rivet is inserted with the head opposite the countersunk end of the hole, the shank of the rivet is driven into the cavity formed by the countersink, and the excess material is removed with a milling tool. A countersink angle of 60° was used throughout. The depths of the countersink used are given in table 1.

Ultimate compressive loads for the 348 specimens were determined in a hydraulic testing machine having an accuracy of one-half of 1 percent of the load. The ends of the specimens were ground accurately flat and parallel in a special grinder, and the method of alinement in the testing machine was such as to insure a uniform bearing over the ends of the specimens.

The with-grain compressive yield strength $\sigma_{\rm CY}$ of the material before forming was found to be as follows: 48.0 ksi (max.), 44.2 ksi (av.), and 40.4 ksi (min.).

RESULTS AND DISCUSSION

The results are presented in figure 3 and table 1. In figure 3, $\overline{\sigma}_f$, calculated simply as the failing load divided by the cross-sectional area of the panel, is plotted against the sum of the thicknesses of sheet and stiffener $\frac{d}{t_S + t_W}$ in order to present the results in a manner similar to that used in references 2 and 3. Figure 3 shows that for all values of $\frac{t_W}{t_S}$ and $\frac{b_S}{t_S}$ investigated the compressive strengths increased with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets.

The type of failure also changed with increasing rivet diameter and decreasing rivet pitch, as is shown in figure 4. For the weakest riveting (see lower left corner of fig. 4), there was a fairly long wave—length bulging of the sheet away from the stiffeners accompanied by numerous rivet failures. As the strength of riveting increased (upward and toward the right on fig. 4) the wave length of the bulge decreased and fewer rivet failures occurred. In order to avoid this bulging altogether and to achieve a plate buckling pattern which varied sinusoidally along and across the sheet at failure, a very strong riveting was required. (See top part of fig. 4.)

These results suggest that the conception of a limited critical range of the ratio of rivet pitch to sheet thickness (the "danger zone" tentatively established in reference 4) for which rivet failures may be expected to reduce the panel strength may be misleading. At

least for rivet pitches smaller than those corresponding to the lower limit of the critical range of reference 4, and for the type of stiffeners tested, perhaps a somewhat truer conception is that the strength for local buckling failure always depends upon both the rivet pitch and diameter as well as upon such other variables as panel proportions.

CONCLUDING REMARKS

Results are presented of tests to determine the effect of varying the rivet diameter and pitch on the compressive strength of flat 24S-T aluminum-alloy Z-stiffened panels of the type for which design charts are available. The present part of the investigation is concerned with panels which have the smallest values of width-to-thickness ratio of the webs of the stiffeners given by the design charts and have such length that failure is by local buckling. The results showed that for these panels, regardless of their stiffener spacing, the compressive strengths increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., August 1, 1947

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS

SHOWING EFFECTS OF VARYING RIVET PITCH AND RIVET DIAMETER

Diam. of rivets,	Depth of countersink,	Pitch of rivets,	Average stress at failing load,	$\frac{P_1}{L/\sqrt{c}}$
(in.)	(in.)	(in.)	(ksi)	(ksi)
		= 1.60 in.; L = 10.40 00; $\frac{b_S}{t_S} = 2\pi^a$; $\frac{b_W}{t_W} = 20$		
1/16	0.035	3/16 3/8 5/8 15/16	43.050 41.450 b36.855 b38.380	1.233 1.180 1.013 1.093
		1 <u>5</u>	29.300	.840
		13/4	26.700	.768
3/32	.040	9/32 3/8 5/8 15/16	44.300 43.500 538.070 540.035	1.303 1.245 1.069 1.140
		15/16	33.400	.950
		13/4	30.700	.891
1/8	.050	3/8 5/8 15/16	44.600 b43.735 b41.710	1.317 1.227 1.186
	-	1 <u>5</u> 16 1 <u>3</u>	34.750 32.200	.990
5/32	.060	15/32 5/8 15/16 15/16	45.000 43.870 40.500 36.100	1.318 1.197 1.142 1.032
		16 13/4	b33.800	•973
3/16	.065	9/16 5/8 15/16	45.340 44.700 40.850	1.329 1.232 1.160
3), 20		1 <u>5</u> 16 1 <u>3</u>	37.600 b _{33.800}	1.077
		3/4	44.485	1.272
1/4	.065	3/4 15/16 1 ⁵ / ₁₆ 1 ³ / ₄	44.485 38.900	1.104
	NORTH TON I WA	13	35.350	1.022

aData for $\frac{b_S}{t_S} = 25$ is from reference 2.

bAverage of two tests.

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, of (ksi)	P ₁ L/ √ C (ks1)
	$t_S = 0.064$ in.; $b_S = 1.00$	1.92 in.; L = 10.02 in $\frac{b_S}{t_S} = 30$; $\frac{b_W}{t_W} = 20$	i.; W = 10.24 in.;	
1/16	0.035	3/16 3/8 5/8 15/16 15/16 13/4	41.640 39.900 36.550 35.200 33.140	1.086 1.042 .952 .927 .865
3/32	.040	9/32 3/8 5/8 15/16 1-5 1-6 1-3	32.310 41.860 42.640 39.400 36.550 31.830	1.103 1.106 1.019 .938
		1 <u>3</u> 3/8	28.160	1.019
1/8	.050	3/8 5/8 15/16 1 <u>5</u> 16 1 <u>3</u>	38.900 36.100 34.050 30.370	.992 .895 .876
5/32	.060	15/32 5/8 15/16 1-2 16 1 ³ / ₄	44.070 42.190 40.620 35.150 31.910	1.146 1.096 1.049 .908
3/16	.065	9/16 5/8 15/16 15/16 14	42.750 43.440 40.000 36.570 33.100	1.116 1.126 1.026 -933
1/4	.065	3/4 15/16 1-5 16 1 ³ / ₄	43.220 43.810 38.370 33.550	1.133 1.140 .984 .860

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets,	Depth of countersink,	Pitch of rivets,	Average stress at failing load,	$\frac{P_1}{L/\sqrt{c}}$
(in.)	(in.)	(in.)	(ksi)	(ksi)
		$b_S = 2.24 \text{ in.; } L = 9.$ $= 1.00; \frac{b_S}{t_S} = 35; \frac{b_W}{t_W} = 35; \frac{b_W}{t$	84 in.; W = 11.84 in.;	
		3/16 3/8 5/8 15/16	38.420 34.540 33.790	0.928 .822 .792
1/16	0.035	15/16	32.340	.794
		12	28.310	.687
		1 <u>5</u> 16 1 <u>3</u>	25.940	.631
		9/32 3/8 5/8 15/16	38.370	.936
		3/8	38.600	.936
	-	5/8	37.090	.900 .851
3/32	.040	15/16	34.980	.786
		15/16	32.350	. 100
		13/4	26.990	.653
		3/8	39.130	-947
Art and the		5/8	37.940	.924
1/8	.050	15/16	39.370	.950
		15/16	33.230	.810
		13/4	28.950	.702
		15/32	40.080	.978
		15/32 5/8 15/16	38.990	.944
5/32	.060	15/16	37.980	.921
		15/16	33.230	.810
		1 <u>-5</u> 16 1 <u>3</u>	30.200	.732
		9/16	38.400	.898
		5/8	39.210	•953
3/16	.065	5/8 15/16	38.360	.930
		15/16	34.240	.832
		15/16 13/4	31.740	.769
	4.4		40.380	.994
		3/4 15/16	40.480	•979
1/4	.065	15	36.280	.883
		1 <u>5</u> 16 1 <u>3</u>	32.590	.794
			NATIONAL ADVISORY	

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\overline{\sigma_f}$ (ksi)	$\frac{P_{\underline{1}}}{L/\sqrt{c}}$ (kei)
100 A	$t_S = 0.064 \text{ in.; } b_S = \frac{t_W}{t_S} =$	2.56 in.; L = 9.64 1.00; $\frac{b_S}{t_S}$ = 40; $\frac{b_W}{t_W}$		
1/16	0.035	3/16 3/8 5/8 15/16 15/16	37.940 36.370 31.040 29.160 26.180	0.868 .839 .719 .669
3/32	.040	9/32 3/8 5/8 15/16 1 ⁵ / ₁₆	38.600 38.440 34.190 34.130 28.290	.892 .886 .787 .784
		13/4	24.320	.560
1/8	.050	3/8 5/8 15/16 1 <u>5</u> 16 1 <u>3</u>	38.660 37.280 34.920 30.400 27.700	.886 .847 .807 .695
5/32	.060	15/32 5/8 15/16 1 <u>-5</u> 16 1 ³	38.360 37.700 37.580 31.620 28.590	.884 .869 .860 .732
3/16	.065	9/16 5/8 15/16 15 16 13	37.960 39.070 37.440 32.930	.872 .897 .867 .756
1/4	.065	3/4 15/16 1 ⁵ / ₁₆ 1 ³ / ₄	38.510 38.460 34.820 31.030	.894 .896 .777

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets,	Depth of countersink,	Pitch of rivets, p (in.)	Average stress at failing load,	$\frac{P_1}{L/\sqrt{c}}$
(in.)	(in.)	(1n.)	(ksi)	(ksi)
(160)	$t_{S} = 0.064 \text{ in.; } b_{S} = \frac{t_{W}}{t_{S}} = 1$	3.20 in.; L = 9.28 i .00; $\frac{bs}{t_S}$ = 50; $\frac{b_W}{t_W}$ = 20	n.; W = 16.64 in.;	100 (100 (100 (100 (100 (100 (100 (100
1/16	0.035	3/16 3/8 5/8 15/16	34.840 33.260 32.270 30.260	0.713 .688 .694 .621
		1 <u>5</u> 16 1 3	25.080 21.800	.511
3/32	.040	9/32 3/8 5/8 15/16	35.510 33.820 34.320 31.080	.768 .697 .731 .634
		1 ⁵ / ₁₆ 1 ³ / ₄	28.620 26.240	.590
1/8	.050	3/8 5/8 15/16	35.520 34.490 33.980	.722 .714 .698
		1 <u>5</u> 16 1 <u>3</u>	28.990 26.960	.595
5/32	.060	15/32 5/8 15/16	34.930 35.010 33.750	.720 .724 .696
		1 <u>5</u> 16 13	32 . 330 26.790	.666
3/16	.065	9/16 5/8 15/16	35.590 35.420 34.340	.742 .729 .703
		$1\frac{5}{16}$ $1\frac{3}{4}$	31.680 28.290	.581
1/4	.065	3/4 15/16 1 2 16 13	34.700 34.590 33.760	.718 .716 .720
		13	29.220	.601

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFEMED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load,	P ₁ L/√6
(111.)	(122.)		(ksi)	(ksi)
421.0	t _S = 0.064 in.; b _S =	3.840 in.; L = 8.92	in.; W = 19.84 in.;	
	tw =]	$\frac{b_8}{t_8} = 60; \frac{b_W}{t_W} = 2$	0	
	t _S	ts tw		
		3/16	31.870	0.629
		3/8	31.720	.629
		5/8	29.610	.585
1/16	0.035	15/16	25.340	.503
		3/8 5/8 15/16 15	23.230	.462
		10	20.760	.416
		13	20.760	.410
7.8		9/32 3/8 5/8 15/16	31.690	.625
		3/8	32.080	.640
	No. of the last of	5/8	31.230 28.100	.616
3/32	.040	15/16		.557
		12	28.210	.563
	I was to be a second	1 <u>5</u> 16 13	22.930	.455
		3/8	32.260	.642
		5/8	31.650	.626
1/8	.050	15/16	31.450	.623
		3/8 5/8 15/16 1 <u>5</u>	27.080	-539
		134	24.740	.488
		15/32	32.470	.636
		5/8	32.570	. 644
5/32	.060	15/32 5/8 15/16	31.770	.632
		15	29.940	.590
		1 <u>5</u> 16 1 <u>3</u>	25.840	.516
		9/16	32.680	.650
		5/8	32.240	.633
3/16	.065	15/16	31.930	.635
		12/16	29.930	.603
		15/16 15/16 16 13/4	25.400	.507
	I K. A.	3/4	32.480	.646
		15/16	32.420	.650
1/4	.065	15	31.260	.62
-/-	THE PART OF STREET	3/4 15/16 15/16 13/4	26.580	.526

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\overline{\sigma}_{f}$ (ksi)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)
		= 4.80 in.; L = 8.48 1.00; $\frac{b_S}{t_S}$ = 75; $\frac{b_W}{t_W}$ = 2	3 in.; W = 24.64 in.;	
1/16	0.035	3/16 3/8 5/8 15/16	29.610 28.150 27.810 26.250	0.572 -536 -523 -499
		15 16 13 4	24.000	.456
3/32	.040	9/32 3/8 5/8 15/16	29.320 28.580 28.510 27.160	.560 .545 .545
		1-5 16 13 4	26.100 22.240	.501
1/8	.050	3/8 5/8 15/16	29.850 28.830 28.970	.569 .549 .553
		1 <u>5</u> 16 1 3	25.800 23.670	.494
5/32	.060	15/32 5/8 15/16	30.010 29.340 29.320 27.680	.565 .555 .561
		1 <u>5</u> 16 1 4	23.550	.452
3/16	.065	9/16 5/8 15/16	29.430 29.340 28.780	.556 .563 .547
		1.5 16 1.3 1.4	28.150 24.160	.464
		3/4 15/16	30.100 29.650	•573 •568
1/4	.065	1 <u>5</u> 16 1 3 4	27.660 24.970	.530

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\overline{\sigma}_{f}$ (ksi)	P ₁ L/VC (ksi)
		= 2.55 in.; L = 0.63 ; $\frac{bS}{tS}$ = 25^{a} ;	9.44 in.; W = 13.39 in bw tw = 20	ı. ;
3/32	0.050	9/32 9/16 7/8 1 <u>7</u> 32 119	42.300 39.300 38.170 35.400	1.412 1.288 1.218
	100.20		34.500	1.129
		2	30.000	.984
1/8	.060	3/8 9/16 7/8 1 ⁷	43.800 40.400 39.700 37.800	1.445 1.321 1.263
		17 32 1 <u>19</u> 32	35.500	1.167
		2	30.240	.984
		15/32 9/16 7/8	b43.590 b42.335 41.050	1.431 1.388 1.310
5/32	.070	17/32	37.850	1.236
		32 1 <u>19</u> 32	35.750	1.168
		2	31.800	1.049
		9/16 7/8	^b 45.150 ^c 41.150	1.451
3/16	.080	17 32 1 <u>19</u> 32	38.800	1.263
			38.150	1.253
		2	31.900	1.042
		3/4 7/8	44.050 b43.000	1.471
1/4	.090	17 32 1 <u>19</u> 32	40.700	1.329
		1	39.800	1.307
	Section 8	5	34.100	1.120

aData for $\frac{b_S}{t_S} = 25$ is from reference 2.

bAverage of two tests. CAverage of three tests.

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\overline{\sigma}_{f}$ (ksi)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)
ts =		06 in.; L = 8.58 ; $\frac{bS}{t_S}$ = 30; $\frac{bW}{t_W}$ =	3 in.; W = 15.94 in.; 20	
		9/32 9/16 7/8	37.780 35.850 35.350	1.153 1.089 1.067
3/32	0.050	1.7 32 1.19 32	34.450 31.690	1.033
		3 ²	30.990	.935
		3/8 9/16 7/8	38.020 37.970 37.210	1.143 1.158 1.141
1/8	.060	1 7 32	34.610	1.055
		1 <u>19</u> 32	32.400	.976
		2	26.010	.781
		15/32 9/16 7/8	37.480 38.140 36.370	1.138 1.168 1.100
5/32	.070	1 <u>7</u> 32 1 <u>19</u>	35.260	1.070
		1 <u>19</u> 32 2	33.790 30.880	1.018
		9/16 7/8	38.970 38.950	1.194
3/16	.080	1 7 32	37.070	1.124
		32 1 <u>19</u> 32	34.840	1.057
1		2	32.130	.973
		3/4 7/8 1-7 32 1-19 32	39.630 38.790	1.200 1.178
1/4	.090	1 <u>1</u> 32	38.540	1.165
		The state of the state of the state of	36.960	1.124
		2	33.630	.973

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, of (ksi)	P ₁ L//c (ksi)
t _S =	0.102 in.; $b_S = 3.5$ $\frac{t_W}{t_S} = 0.63$; $\frac{b}{t}$	7 in.; L = 8.24 $\frac{S}{S}$ = 35; $\frac{b_W}{t_W}$ = 20	in.; W = 18.49 in.;	
7457-4 940-1 140-1		9/32 9/16 7/8	37·340 33·790 33·320	1.157 1.001 1.009
3/32	0.050	1 7 32 119	31.480 28.630	·953
		32	30.650	.926
		3/8 9/16 7/8	36.040 36.030 35.000	1.074 1.094 1.037
1/8	.060 1.7 32 1.19	17 32 119 32	33.880	•999 •942
		2	29.230	.894
5/32	.070	15/32 9/16 7/8 1-7	36.120 34.890 35.930 32.440	1.078 1.037 1.096
		32 1 <u>19</u> 32	30.850	.944
		2	30.430	.919
		9/16 7/8	38.050 36.270	1.179 1.105
3/16	.080	1.7 32 1.19 32	35.570 32.850	1.085
		32	30.040	.905
	1-		^b 36.310 36.940	1.073
1/4	.090	3/4 7/8 1 <u>7</u> 32 1 <u>19</u> 32	35.080	1.037
			34.720	1.033
	AND INC.	2	31.730	.952

bAverage of two tests.

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of nivets, p (in.)	Average stress at failing load, $\overline{\sigma}_{\mathbf{f}}$ (ksi)	$\frac{P_{i}}{L/\sqrt{c}}$ (ksi)
		= 4.08 in.; L = 7 $63; \frac{bs}{t_S} = 40; \frac{b_W}{t_W}$.92 in.; W = 21.04 in	1.;
3/32	0.050	9/32 9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32	33.610 33.180 32.200 28.960 26.970 25.810	1.012 1.013 .937 .887 .833
1/8	.060	3/8 9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32	34.580 34.220 33.530 32.490 30.790 29.420	.997 .997 .977 .952 .939
5/32	.070	15/32 9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32	33.480 34.370 34.410 33.390 29.700 27.810	.963 1.001 1.062 1.027 .908
3/16	.080	9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32	34.870 34.300 33.830 32.550 30.540	1.019 1.049 .995 .997
1/4	.090	3/4 7/8 1 <u>7</u> 32 1 <u>19</u> 32	34.310 34.720 33.520 33.250 29.480	1.033 1.067 .981 1.019

TABLE 1 .- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\overline{\sigma}_{f}$ (ksi)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)
ts		= 5.10 in.; L = $\frac{b_W}{t_S}$ = 50; $\frac{b_W}{t_W}$	7.40 in.; W = 26.14 in. = 20	;
		9/32 9/16 7/8	29.500 29.660 29.440	0.866 .876
3/32	0.050	9/16 7/8 1 7 32 1 <u>19</u>	28.730	.883
		32	26.820	.806
1/8	.060	3/8 9/16 7/8 1 <u>7</u>	29.460 29.340 30.710 29.790	.869 .876 .945
1/0 8		1 7 32 1 19 32 32	^b 26.810 27.430	.798
5/32	.070	15/32 9/16 7/8 17 32 119 32	29.620 29.860 31.110 30.380 27.960	.873 .881 .941 .944
		32	28.960	.890
3/16	.080	9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32	32.830 31.120 30.510 29.890	1.033 .944 .943
		32	27.340	.826
1/4	.090	3/4 7/8 1 <u>7</u> 32 1 <u>19</u>	30.860 29.840 30.600 30.220	.922 .883 .947
		32	28.990	.871

b Average of two tests.

TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\overline{\sigma}_f$ (ksi)	$\frac{P_{i}}{L/\sqrt{c}}$ (ksi)
		= 6.12 in.; L = 0.63 ; $\frac{bs}{ts}$ = 60 ; $\frac{1}{4}$	= 6.96 in.; W = 31.24 i	n.;
3/32	0.050	9/32 9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32	28.800 b29.080 b28.810 b27.760	0.876 .888 .876 .848
		1 <u>19</u> 32 2	27.060 b27.760	.837
1/8	.060	3/8 9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32	29.460 29.200 28.670 26.570	.895 .893 .887 .828
		1 <u>19</u> 32 2	^b 27.320 26.930	.836
5/32	.070	15/32 9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32	29.470 29.090 29.680 29.320 29.320	.891 .890 .919 .909 .908
3/16	.080	9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32 2	29.830 28.760 29.420 28.540 30.260	.918 .868 .908 .874
1/4	.090	3/4 7/8 1 <u>7</u> 32 1 <u>19</u> 32	29.660 29.510 29.190 28.560 27.830	.893 .899 .900 .882

bAverage of two tests.

TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Concluded

Diam. of rivets d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\overline{\sigma}_f$ (ksi)	$\frac{P_{1}}{L/\sqrt{c}}$ (ksi)
1-03		= 7.65 in.; L = 0.63; $\frac{b_S}{t_S}$ = 75; $\frac{b_W}{t_W}$	6.42 in.; W = 38.89 in	.;
3/32	0.050	9/32 9/16 7/8 1 7 32 1 <u>19</u> 32	25.830 24.880 23.280 23.260 21.000 18.820	0.829 .801 .751 .748 .661
1/8	.060	3/8 9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32	26.520 26.610 24.430 23.720 22.005	.851 .860 .784 .763 .710
5/32	.070	15/32 9/16 7/8 1 <u>7</u> 32 1 <u>19</u> 32	25.780 26.710 25.490 24.300 24.480 23.980	.831 .841 .820 .781 .793
3/16	.080	9/16 7/8 1-7 32 1 <u>19</u> 32 2	27.550 26.000 25.070 25.140 21.380	.924 .819 .806 .813
1/4	.090	3/4 7/8 1 <u>7</u> 32 1 <u>19</u> 32 2	26.380 27.220 24.920 24.150 26.000	.847 .854 .787 .778 .835

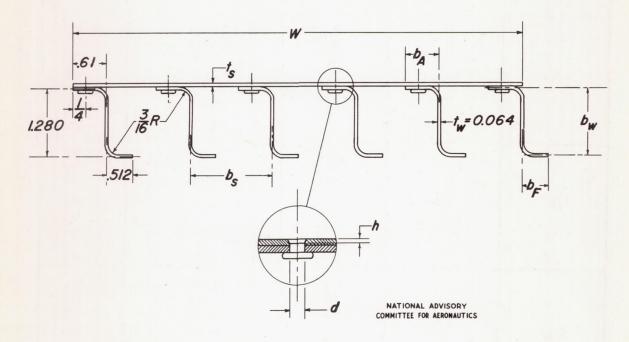
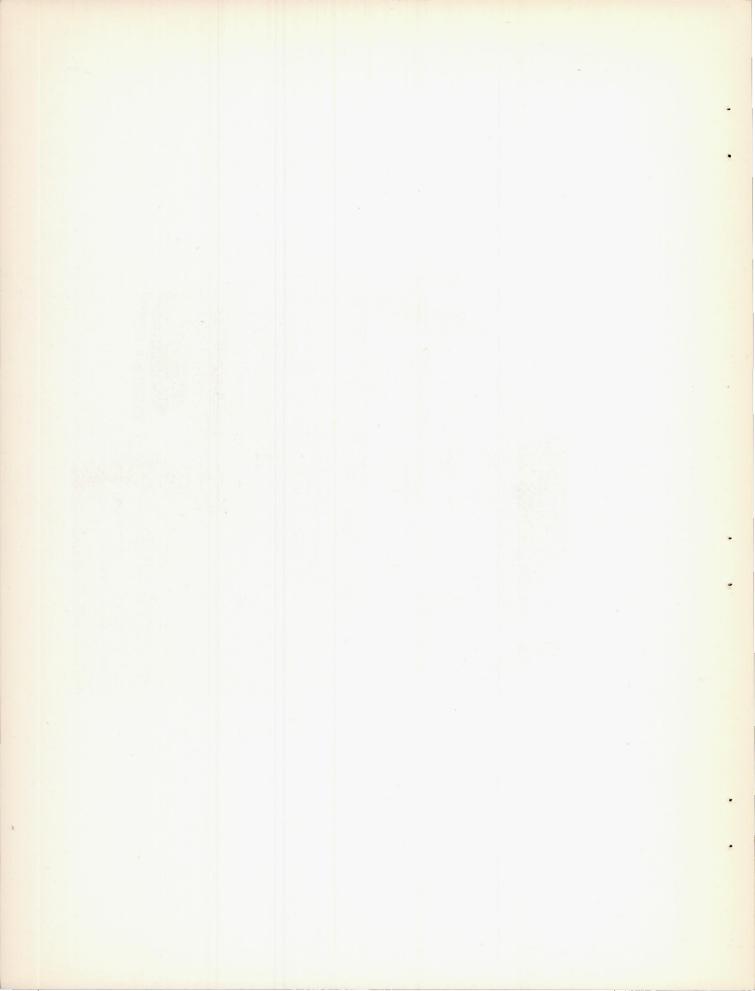


Figure I.— Cross section of test specimens.



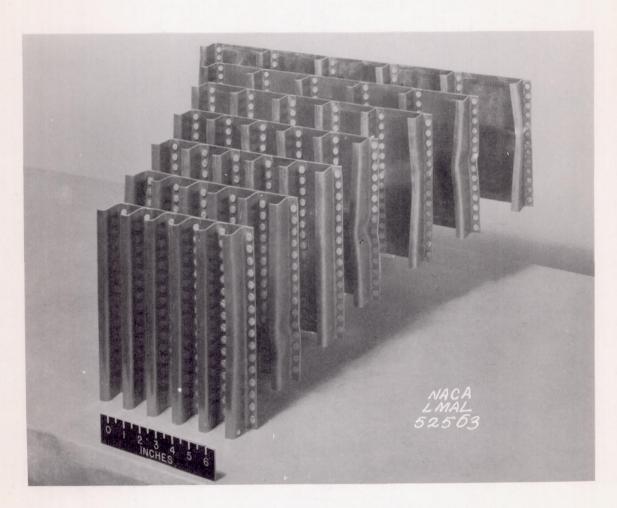


Figure 2.- Typical specimens after failure.

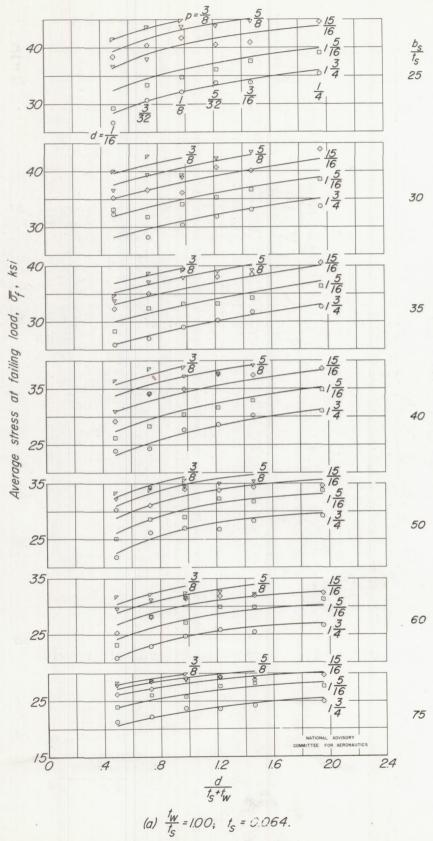


Figure 3.-Variation in compressive strength of panels with rivet diameter.

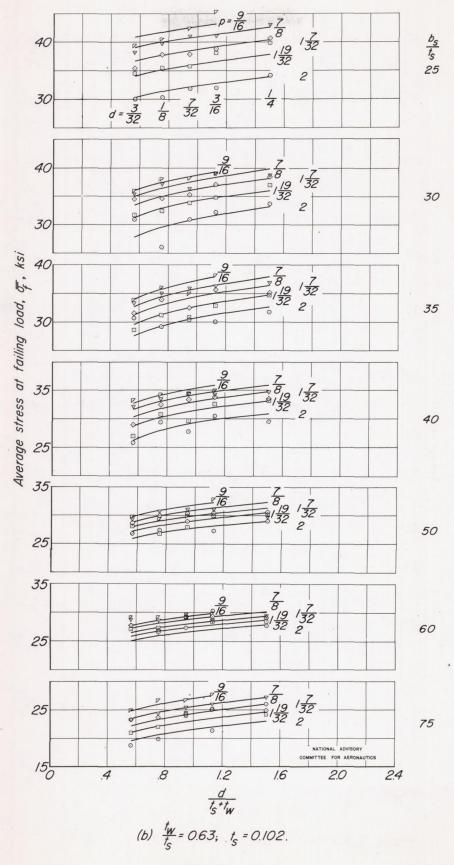
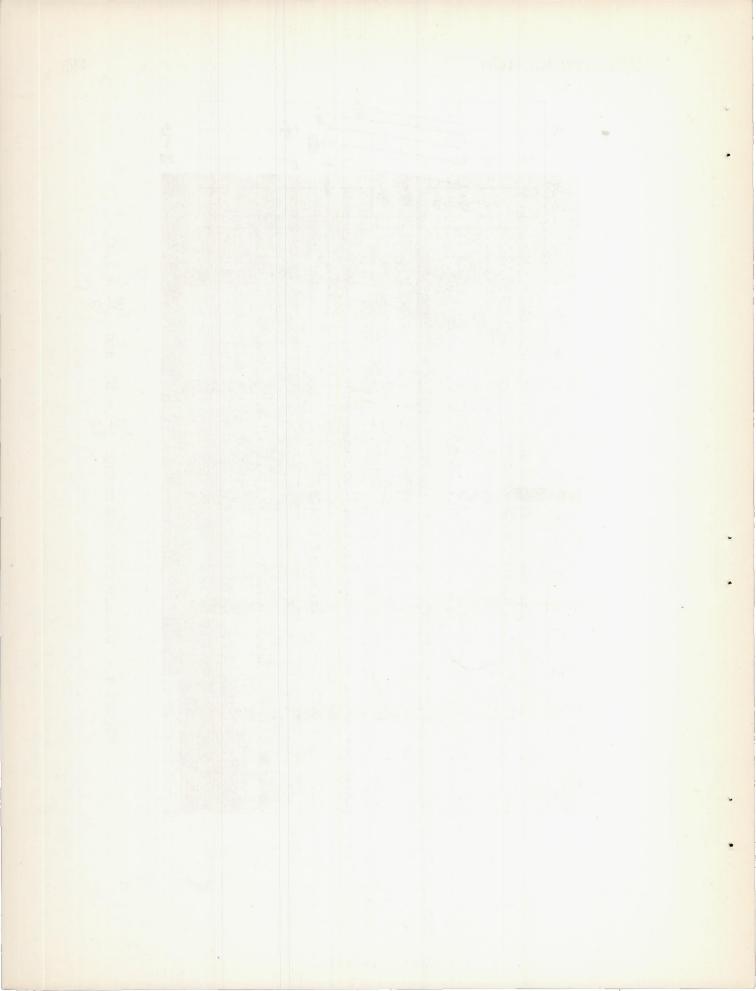


Figure 3.-Concluded.



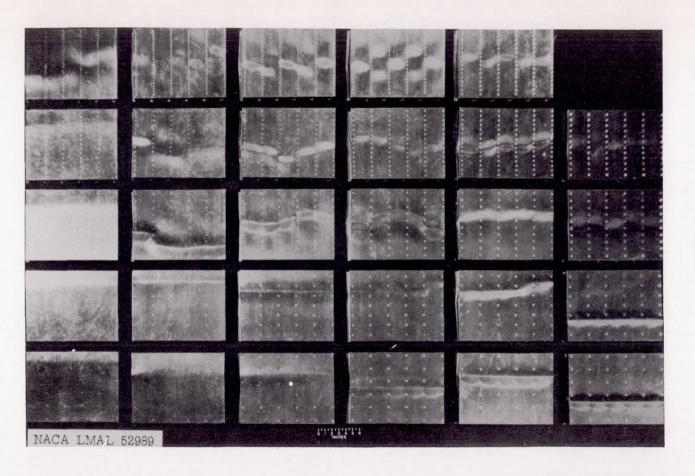


Figure 4.- Failure of panels having $\frac{b_S}{t_S} = 30$ and $\frac{t_W}{t_S} = 1.00$.